# How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana

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**Abstract:**

Why do men and women adopt agricultural technologies at different rates? Evidence from Ghana suggests that gender-linked differences in the adoption of modern maize varieties and chemical fertilizer are not attributable to inherent characteristics of the technologies themselves but instead result from gender-linked differences in access to key inputs.

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## 1. Introduction

In recent years, development practitioners have become increasingly interested in questions relating to the distributional impacts of technical change in agriculture. Scientific breakthroughs such as the much-publicized green revolutions in wheat and rice have brought about dramatic productivity gains in many of the world's leading cereal crops, but the persistence of chronic malnutrition among a significant portion of the world's population has led to the realization that millions of people still lack reliable access to sufficient quantities of food. This realization has caused increased attention to be directed at the technology adoption process. If certain groups are not adopting new technologies, or adopting them at a lower rate, then we need to determine why, because only by understanding the reasons will we be able to develop improved technologies that are appropriate for all. In particular, concern has been expressed that gender may play an important role in influencing technology adoption decisions.

## 2. Research objectives

Using empirical data from Ghana, this paper addresses two questions about gender and technology adoption. First, does including gender as an explanatory variable in standard regression models add to our understanding of the technology adoption process? Second, are frequently observed differences in the rates at which men and women adopt improved technology attributable to gender-linked differences in access to complementary inputs, such as land, labor, and extension services?

These questions are of obvious practical importance, because they go directly to the issue of whether gender-related differences in adoption patterns can be attributed to innate characteristics of improved technologies themselves or result from other, external factors. The distinction is crucial, because if gender directly affects the technology adoption process (and more specifically, if women face special obstacles in adopting improved technology), then it may be necessary to modify research and extension strategies to ensure that the distribution of benefits associated with the adoption of technological innovations are less based on gender. If, on the other hand, differential rates of adoption are caused by unequal access to complementary inputs that affect adoption indirectly, then it may be more important to work on improving access to these complementary inputs by disadvantaged groups, especially women.

Maize in Ghana makes a particularly appropriate subject for an inquiry into the links between gender and adoption for at least three reasons. First, maize is Ghana's most important cereal crop and is grown by the vast majority of rural households (except in the Sudan savannah zone of the far north). Second, it is widely consumed throughout the country. Third, it is cultivated by both men and women, and women frequently manage their own maize fields, contribute an important proportion of overall labor requirements, and exercise complete discretion over the disposal of the harvest. Because maize production activities are managed autonomously by men and women, technology choice decisions tend to be made independently, which makes it easier to distinguish gender-related dimensions of the adoption process.

We address the influence of gender on technology adoption by examining factors affecting the uptake of two improved maize production technologies: modern varieties (MVs)[1] and fertilizer. These technologies were developed and promulgated through the Ghana Grains Development Project, an 18-year research and extension project that was established to develop and disseminate improved technologies for maize and grain legumes. An impacts study carried out following the termination of the project revealed that both MVs and fertilizer have been adopted less extensively by women than by men; during the 1997 cropping season, 39.0% of female farmers planted MVs compared to 59.0% of male farmers, and 16.2% of female farmers applied fertilizer to their maize fields compared to 22.5% of male farmers (Morris *et al.*, 1999). The objective of our inquiry is thus to identify the factors that account for the differential rates of adoption.

## 3. Data

Data on the adoption of MVs and fertilizer in Ghana were collected through a survey of maize growers carried out between November 1997 and March 1998. A three-stage,

1 As used here, the term *modern varieties* (MVs) refers to improved open-pollinating varieties (OPVs) and hybrids developed by a formal plant breeding program.

clustered, randomized procedure was used to select a representative sample of 420 maize farmers located in 60 villages throughout the country. These farmers were questioned at length about their maize production, consumption, and marketing practices; their preferences for different maize varietal characteristics; and their knowledge of and access to improved inputs, including seed and fertilizer (see Morris *et al*., 1999).

Many technology adoption studies distinguish between the *rate of adoption* (defined as the proportion of farmers that adopt a given technology, regardless of the level of use) and the *intensity of adoption* (defined in terms of the level of use of the technology, e.g., the proportion of the farmer's land planted to MVs or the quantity applied of fertilizer). In Ghana, farmers who adopt MVs tend to plant them over their entire landholdings, so the intensity measure usually takes on a value of either 0% or 100%. The rate of adoption measure therefore ends up being very similar to the intensity of adoption measure. In the case of fertilizer, the available data do not enable us to determine the amount of fertilizer applied by each farmer. For these reasons, we choose to focus only on rates of adoption.

## 4. Adoption model

Maize farmers in Ghana must decide whether to adopt MVs, fertilizer, or both. The benefits realized when both technologies are adopted jointly exceed the sum of the benefits realized when each one is adopted separately, so we expect that the decision to adopt one technology is affected by the decision to adopt the other. Because the two adoption decisions are linked, we use a two stage probit approach. In the first stage, the full set of estimators is used to predict the probability of adopting either fertilizer or MVs. In the second stage, the predicted values for MV adoption and fertilizer adoption are included as independent variables in the final set of estimations. Because of the hypothesized endogeneity of the system, the two equations are estimated simultaneously. Bootstrapping procedures are used to generate consistent standard errors.[2]

The basic model is specified as follows:

$$\begin{aligned} MVadopter &= \beta_1 X_1 + \beta_2\, fertadopter + \varepsilon_1 \\ fertadopter &= \beta_3 X_2 + \beta_4\, MVadopter + \varepsilon_2 \end{aligned}$$

where *MVadopter* and *fertadopter* are dummy variables indicating whether the farmer adopted MVs and fertilizer, and $X_1$ and $X_2$ are vectors of variables expected to affect the technology adoption decision. These variables are discussed in detail below.

Dummy variables are included for three *ecological zones* in which maize is cultivated: the coastal savannah, the transition zone, and the guinea savannah (a fourth zone, the forest zone, serves as the reference). The main purpose of the zonal dummy variables is to control for agro-climatic differences that could affect the profitability of the two technologies. However, since the northern part of the country, including virtually all of the guinea savannah zone and portions of the transition zone, is inhabited mainly by Muslim ethnic groups among which women tend to be less responsible for agriculture, the zonal dummy variables may also pick up some cultural variability, which could be linked to gender effects.

Several characteristics of the farmer are included as covariates. The farmer's *gender* is represented by a dummy variable. Unlike many other studies, we use the gender of the farmer, rather than the gender of the household head. This allows us to examine the behavior of female farmers in male headed households. The farmer's *age* is also included, as is the farmer's *education* (expressed as the number of years of formal schooling completed).

The literature on technology adoption suggests that technology adoption decisions may also be affected by a number of other factors (Feder *et al.*, 1985; Feder and Umali, 1993). The amount of *land owned* by the farmer is included as an explanatory variable, because even though MVs are expected to be scale neutral, wealthier farmers (i.e., those with more land) are more likely to be able to afford fertilizer. Since agricultural extension

2 We appreciate advice received from Barry Goodwin on the use of bootstrapping procedures.

agents serve as an important source of technical information and improved inputs, the number of *extension visits* received by the farmer is expected to be positively correlated with the probability of adoption. Market access may also affect the adoption decision, so an index was created to reflect the *level of infrastructure* present in the farmer's village (the index was calculated based on the presence or absence of a tarred road, a good feeder road, reliable transportation, and a physical market). Since adopting a new technology often implies a need for additional labor, *labor availability* is frequently associated with successful adoption. In Model 1, *household size* is used as a simple measure of labor availability. The literature on gender and farming in Africa (see Doss, 1999) suggests that men's labor and women's labor are not interchangeable, however, so in Model 2 we account for labor availability by including as separate explanatory variables the number of *adult men*, *adult women*, and *children* in the farmer's household.

For purposes of identifying the system of equations, we need at least one variable that is linked only to MV adoption, and at least one variable that is linked only to fertilizer adoption. To identify the MV adoption equation, we include a *seed source* variable that indicates whether the seed planted in a given maize field was farm-saved or externally acquired (e.g., obtained from another farmer, from an extension agent, or from a shop). To identify the fertilizer adoption equation, we include a *soil fertility* variable based on the field's cropping history. If the field had been fallow prior to the year of the survey, we used the number of years that the field had been fallow, so the variable can take on positive or negative values.

## 5. Empirical results

Empirical results obtained from estimating the two models are summarized in Table 1. The consistency of the standard errors was ensured by running the bootstrapping procedure for 1,000 iterations. Three aspects of the results are noteworthy.

First, in both models the gender variable lacks significant explanatory power.

Second, many of the other explanatory variables have the expected signs and are statistically significant. In the MV adoption equation, ecological zone, level of education, amount of land owned, number of extension visits, level of infrastructure, and number of adult males in the household are positively associated with the probability of adoption. In the fertilizer adoption equation, ecological zone, farmer's age, amount of land owned (Model 1 only), number of extension visits, level of infrastructure, and soil fertility are positively associated with the probability of adoption.

Third, several of the explanatory variables lack statistical significance. With the exception of the coefficient on the number of adult men in the MV adoption equation, none of the coefficients on the various measures of labor availability are statistically significant. This could indicate that labor availability does not affect MV and fertilizer adoption decisions, or it could simply mean that the variables we have used (based on the number of people living in the farmer's household) are not good indicators of the ability of Ghanaian farmers to mobilize labor to work in their maize fields. Somewhat more puzzling, neither of the estimated coefficients on the (fitted) endogenous variables shows significant explanatory power, suggesting that MV and fertilizer adoption decisions may be taken independently, rather than jointly.

## 6. Access to key inputs

The results presented in Table 1 indicate that gender *per se* is not significantly associated with MV or fertilizer adoption rates. But is gender linked to factors that indirectly influence adoption behavior? In particular, since adoption is associated with land ownership, number of contacts with the extension service, and number of adult men in the farmer's household (MV adoption only), are these factors correlated with gender? Descriptive statistics and simple linear regressions can help to determine if women and men enjoy equal access to land, labor, and extension services.

*Land:* Wealth is often positively associated with the adoption of new technologies, because wealthier farmers are better able to bear risk and thus are more likely to try new technologies. In rural Ghana, land ownership provides a good measure of wealth. Clearly, land ownership is related to gender; women tend to own smaller plots of land than men, and a greater proportion of women are landless (Table 2). The determinants of land ownership were explored using a tobit approach. Controlling for the farmer's age, residency status (native or settler), and marital status, as well as for ecological zone and level of infrastructure, women farmers on average were found to have significantly less access to land (Table 3).

*Labor:* Throughout many parts of sub-Saharan Africa, women have greater difficulty than men obtaining labor, especially male labor needed for land preparation activities (e.g., clearing, burning, plowing). Within our sample, women farmers live in households that contain slightly fewer men on average, except for the transition zone (Table 4). Household size varies by zone, but within zones there do not appear to be significant differences between the sizes of households of male and female farmers. The data thus suggest that male and female maize farmers live in households that contain approximately the same number of adult household members. What these numbers cannot tell us, however, is whether male and female maize farmers have equal access to the labor of other household members. In many parts of Africa, men have claim over women's labor, but women do not have similar claim over men's labor. Therefore, the data do not allow us to conclude that female farmers definitely have access to male labor; they simply indicate that the households in which female farmers live include men who could potentially provide labor.

*Extension contacts:* The uptake of new technologies is often influenced by the farmer's contact with extension services, since extension agents provide improved inputs and technical advice. Within our sample, the frequency of contact with extension agents is strongly associated with the gender of the farmer. On average, women reported fewer contacts with extension agents, and a larger proportion of women reported no extension contacts at all (Table 5). In interpreting the data in Table 5, it is important to keep in mind that differences in the number of reported contacts with extension agents may not be attributable to the gender of the farmer, but instead could result from other factors that happen to be correlated with the gender of the farmer. For example, it is plausible that extension agents might prefer to visit farmers with more land or a larger area planted to maize, both of which happen to be correlated with gender.

On the whole, these findings suggest that male and female maize farmers in Ghana do not enjoy equal access to land and to agricultural extension services. The data are less conclusive regarding the availability of and access to labor, especially male labor within the household.

## 7. Discussion

In view of this evidence, what can we conclude about the two questions posed at the beginning of the paper?

First, in this example involving maize in Ghana, after we control for the farmer's age and level of education, access to land and labor, contact with the extension service, and market access, there is no significant association between the gender of the farmer and the probability of adopting MVs and/or fertilizer. Since men and women have adopted MVs and fertilizer at different rates, this finding shows the critical importance of correctly specifying adoption models. Failure to control for gender-linked factors can lead to misleading conclusions about the importance of gender *per se* as an explanatory factor. One caveat should be noted, however; the sample included only farmers identified as "maize farmers." If either men or women were disproportionately excluded from the sample because they were not considered maize farmers, the results could be biased.[3]

Second, access to land and number of extension contacts are clearly correlated with gender. However, a number of questions remain. For example, we cannot determine from the data whether women have access to the same quality of land as men. Nor can we determine whether the quantity and/or quality of information provided by extension workers differs depending on the gender of the farmer. And as previously noted, although the number of men in the household is correlated with MV adoption, simply counting the

3 The proportion of women farmers in the sample corresponds to the percent of women growing maize identified through the 1991/92 round of the Ghana Living Standard Survey (reported in Doss, 1997),

number of household members does not tell us whether women are able to mobilize the labor that is present in their households to work in their maize fields. Thus, although there are observed differences in access to land, extension visits, and male household labor, the unobserved differences may be even more significant.

On the whole, these results from Ghana suggest that technology adoption decisions depend primarily on access to resources, rather than on gender *per se*. This conclusion should be interpreted with caution, however, because it does not necessarily mean that MVs and fertilizer are gender-neutral technologies. If adoption of MVs and/or fertilizer depends on access to land, labor, or other resources, and if in a particular context men tend to have better access to these resources than women, then in that context the technologies will not benefit men and women equally. Policy changes thus may be needed to increase women's access to the key resources; alternatively, it may be desirable to modify research efforts by deliberately targeting technologies that are particularly suited for the resources that are available to women. The bottom line is that it is important to examine both the technology itself and the physical and institutional context in which the technology is implemented in order to predict whether it will be adopted successfully by women as well as men.

however, so we believe these results are not affected by sample selection bias.

**Table 1. Adoption of improved technologies (simultaneous probit results).**

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. error | | Coefficient | Std. error | |
| ***MV adoption*** | | | | | | |
| Female | 0.115 | 0.203 | | 0.058 | 0.204 | |
| Coastal savannah | 0.607 | 0.359 | * | 0.606 | 0.274 | ** |
| Transition zone | 0.926 | 0.368 | ** | 0.998 | 0.329 | *** |
| Guinea savannah | 0.882 | 0.495 | * | 0.937 | 0.368 | ** |
| Age | 0.006 | 0.011 | | 0.006 | 0.007 | |
| Education | 0.059 | 0.019 | *** | 0.060 | 0.018 | *** |
| Land owned | 0.066 | 0.032 | ** | 0.064 | 0.027 | ** |
| Extension | 0.082 | 0.036 | ** | 0.084 | 0.031 | *** |
| Infrastructure | 0.179 | 0.134 | | 0.202 | 0.098 | ** |
| Men | | | | 0.112 | 0.051 | ** |
| Women | | | | -0.065 | 0.054 | |
| Children | | | | -0.018 | 0.027 | |
| Household size | 0.005 | 0.016 | | | | |
| New seed | 0.979 | 0.259 | *** | 0.999 | 0.201 | *** |
| Predicted fertilizer user | -0.068 | 0.437 | | -0.069 | 0.236 | |
| Constant | -2.301 | 0.857 | *** | -2.316 | 0.639 | *** |
| | | | | | | |
| ***Fertilizer adoption*** | | | | | | |
| Female | -0.098 | 0.221 | | 0.053 | 0.228 | |
| Coastal savannah | 0.421 | 0.242 | * | 0.442 | 0.249 | * |
| Transition zone | 0.686 | 0.247 | *** | 0.652 | 0.257 | ** |
| Guinea savannah | 0.461 | 0.297 | | 0.457 | 0.317 | |
| Age | -0.016 | 0.008 | ** | -0.016 | 0.008 | ** |
| Education | 0.003 | 0.019 | | 0.003 | 0.019 | |
| Land owned | 0.032 | 0.018 | * | 0.031 | 0.020 | |
| Extension | 0.044 | 0.020 | ** | 0.043 | 0.021 | ** |
| Infrastructure | 0.181 | 0.078 | ** | 0.169 | 0.081 | ** |
| Men | | | | 0.061 | 0.050 | |
| Women | | | | 0.070 | 0.050 | |
| Children | | | | 0.032 | 0.027 | |
| Household size | 0.017 | 0.013 | | | | |
| Years cropped | 0.041 | 0.017 | ** | 0.042 | 0.017 | ** |
| Predicted MV user | 0.009 | 0.050 | | 0.010 | 0.053 | |
| Constant | -1.255 | 0.411 | *** | -1.251 | 0.411 | *** |

Note: * significant at .10 level, ** significant at .05 level, and *** significant at .00 level.

**Table 2. Land ownership by gender (% of maize farmers).**

| Land ownership | Men | Women | Total |
|---|---|---|---|
| 0 ha | 20.6 | 24.8 | 21.7 |
| < 1 ha | 6.3 | 16.2 | 8.8 |
| 1 to 3 ha | 18.7 | 26.7 | 20.7 |
| 3 to 5 ha | 17.5 | 19.0 | 17.9 |
| 5 to10 ha | 23.5 | 9.5 | 20.0 |
| > 10 ha | 13.3 | 3.8 | 11.0 |
| Total | 100.0 | 100.0 | 100.0 |

Source: 1998 CRI/CIMMYT survey. Columns may not sum to 100 due to rounding errors.

**Table 3. Determinants of land ownership (tobit estimates).**

| | Estimated coefficient | Standard error | Significance level |
|---|---|---|---|
| Female | -1.455 | 0.707 | ** |
| Resident Status | 3.574 | 0.670 | *** |
| Age | -0.003 | 0.003 | |
| Infrastructure | 0.215 | 0.268 | |
| Coastal Savannah | -2.598 | 0.860 | *** |
| Guinea Savannah | 5.100 | 0.795 | *** |
| Transition zone | -0.474 | 0.093 | |
| Marital status | -5.60 E-03 | 0.79 | |
| Log Likelihood = -1109.25 | | | |

Note: * significant at .10 level, ** significant at .05 level, and *** significant at .00 level.

**Table 4. Household size and composition, by gender of farmer.**

| | Coastal Savannah | | Forest | | Transition | | Guinea Savannah | |
|---|---|---|---|---|---|---|---|---|
| | **Male farmers** | **Female farmers** | **Male farmers** | **Female farmers** | **Male farmers** | **Female farmers** | **Male farmers** | **Female farmers** |
| Men | 3.05 | 2.54 | 2.42 | 2.12 | 2.34 | 2.86 | 4.30 | 3.00 |
| Women | 2.85 | 2.88 | 2.34 | 2.18 | 2.80 | 3.95 | 4.00 | 2.00 |
| Children | 3.53 | 4.96 | 3.48 | 3.28 | 3.61 | 4.91 | 7.15 | 8.00 |
| Total | 9.43 | 9.70 | 8.23 | 8.04 | 8.76 | 9.79 | 15.45 | 15.39 |

Source: 1998 CRI/CIMMYT survey.

**Table 5. Reported number of contacts with extension agents, by gender of farmer.**

| | Coastal Savannah | | Forest | | Transition | | Guinea Savannah | |
|---|---|---|---|---|---|---|---|---|
| | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** |
| 0 | 26 | 19 | 81 | 38 | 27 | 15 | 39 | 0 |
| 1 to 3 | 14 | 2 | 21 | 17 | 11 | 3 | 24 | 2 |
| 4 to 7 | 6 | 1 | 11 | 0 | 2 | 3 | 9 | 0 |
| >8 | 14 | 2 | 19 | 2 | 1 | 1 | 10 | 0 |
| Total | 60 | 24 | 132 | 57 | 41 | 22 | 82 | 2 |

Source: 1998 CRI/CIMMYT survey.

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